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ECONOMIC IMPACTS OF CHANGES IN SALINITY LEVELS OF THE COLORADO RIVER

**UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Denver, Colorado**

**Prepared by: Alan P. Kleinman
Glade J. Barney
Sigurd G. Titmus**

February 1974

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OF THE COLORADO RIVER

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U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado

February 1974

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ECONOMIC IMPACTS OF CHANGES IN SALINITY LEVELS OF THE COLORADO RIVER

There appear to be many impacts resulting from changes in salinity of the waters of the Colorado River. By far the most significant impact is the economic effect of using water with a high concentration of dissolved solids. Given here is an analysis of available data from which is developed the best possible estimate of these economic impacts. The estimates are intended to be used as benefit values in evaluating the justification of salinity control measures and as a quantification of the salinity externalities associated with proposed water resource development projects.

I. The Problem Setting

The waters of the Colorado River are progressively increasing in salinity. The principal dissolved constituents in Colorado River waters are the cations - calcium, magnesium, and sodium, and the anions - sulfate, chloride, and bicarbonate. These, and small amounts of other dissolved constituents, are commonly referred to as salinity. Increasing concentrations of dissolved mineral salts threaten to become a major economic problem for users of Colorado River water.

At the headwaters, the average salinity in the Colorado River is less than 50 mg/l and progressively increases downstream until, at Imperial Dam, the present condition is 865 mg/l. Projections of future salinity suggest values of about 1,200 mg/l at Imperial Dam by the year 2000. Should such salinity increases be realized, severe economic impacts would affect agricultural and municipal users in the Lower Basin.

Salinity increases result from two processes: salt loading and salt concentrating. Salt loading increases the amount of salt for a given amount of water, and salt concentrating decreases the amount of water for a given amount of salt. Salt loading is the addition to the river system of mineral salts from natural and manmade sources. Salt concentrating is the rise in salinity through stream-flow depletions which concentrate the salt burden in the river system into a lesser volume of water.

The amount of salt in water directly influences the utility of the water, and increased salt concentrations typically have a detrimental impact on water users. Such detriments include decreased productivity and/or increased production costs for both agricultural and industrial water users. In household uses, the detriments include lowered palatability of drinking water, reduced life of equipment coming in contact with water and, at higher concentrations of some elements, adverse health effects.

The U.S. Environmental Protection Agency (EPA) has calculated in a study conducted over the period 1960 to 1969 (References 6-9) potential damage from salinity. Total penalty costs, defined as marginal costs of increases in salinity concentrations above 1960 base conditions, are the sum of direct penalty costs incurred by water users and indirect penalty costs imposed on the economy of the region. Irrigated agriculture accounted for the major portion of these penalty costs.

II. The Need for Evaluation

Salinity of waters in the Colorado River Basin could be expected to continue to increase as basin development continues in the absence of any action to control salinity. The seven Colorado River basin states have joined with the Environmental Protection Agency in the development of salinity regulations for the river. They have been instrumental in securing passage of the Colorado River Basin Salinity Control Act (P.L. 93-320), which authorizes 4 salinity control units identified by the Colorado River Water Quality Improvement Program and provides for continued investigation of 12 other units by the Bureau of Reclamation. Expected growth of municipal, domestic, industrial, irrigation, and recreational uses of water will add mineral constituents and deplete the flow of the Colorado River. All phases of the basin economy are expected to expand in the future, requiring increased water use. As the entire basin economy develops, the salinity problem will be further aggravated.

Salinity adversely affects the water supply for a population exceeding 10 million people and over 1 million acres of irrigated land in the Lower Colorado River Basin. Salinity also affects water users in Mexico. As salinity levels rise, the net economic return from agriculture decreases and municipal and industrial water users experience significantly increasing costs as salinity levels rise above 500 mg/l, the maximum recommended in the U.S. Public Health Service Drinking Water Standards.

As an indication of the magnitude of salinity damages, the EPA estimated (for 1970) total annual economic detriments to be \$16 million. If water resource development proceeds as proposed and no salinity controls are implemented, it is estimated that the detriments would increase to \$28 million in 1980 and \$51 million in 2010. If future water resource development is limited to those projects under construction, estimated annual detriments would increase to \$21 million in 1980 and \$29 million in 2010. Detriments to water users in Mexico and to recreation and fishery users in the Salton Sea are not included in these EPA estimates but are believed to be substantial.

Alternatives suggested for salinity control in the Colorado River Basin include (1) augmentation of the basin water supply, (2) reduction of salt loads by structural measures as well as management alternatives, and (3) curtailment of future water resource development. The feasibility and desirability of these three salinity control alternatives are influenced to a large degree by the economics of such actions and

the relative justification from a benefits and costs viewpoint, the recognition of water rights, and the political and institutional forces surrounding each alternative.

It is therefore necessary from the national economic efficiency viewpoint to estimate as accurately as possible the economic impacts of changes in salinity levels upon users of the waters of the Colorado. The economic value of the reduction in salinity levels resulting from mitigation measures is necessary to judge the desirability of such measures. Similarly, the negative economic value of increases in salinity resulting from the salt loading effect of return flows of water development projects is necessary to judge the desirability of such development plans.

The impacts of changing salinity include economic, fish and wildlife, recreation, environmental, and others. While recognizing that many other effects of salinity changes exist, the overriding concern addressed here deals with the monetary effects upon direct users of Colorado River water.

III. Economic Effects of Salinity

Evaluation of possible salinity effects on basin water users indicates that the major quantifiable adverse effects are primarily limited to agricultural, municipal, and industrial uses.

A. Physical Effects, Alternatives, and Procedures

1. Agriculture. Salinity effects on agricultural uses are manifested primarily by limitations on the types of crops that may be irrigated with a given water supply and by reductions of crop yields as salinity levels increase. Other conditions being equal, as salinity levels increase in applied irrigation water, salinity levels in the root zone of the soil also increase.

Because different crops have different tolerances to salts in the root zone, limits are placed on the types of crops that may be grown. When salinity levels in the soil increase above the threshold levels of a crop, progressive impairment of the crop growth and yield results. Irrigation water which has a high percentage of sodium ions may also affect soil structure and cause adverse effects on crop production.

2. Municipal. Domestic uses comprise the major utilization of municipal water supplies. Total hardness, a parameter closely related to salinity, is of considerable interest in assessing water quality effects on these uses. Increases in the concentration of salinity and hardness lead to added soap and detergent consumption, corrosion and scaling of metal water pipes and water heaters, accelerated fabric wear, added water softening costs, and in extreme cases, abandonment of a supply. By most hardness measures, raw water supplies derived from the Colorado River at or below Lake Mead would be classified as very hard.

3. Industrial. Boiler feed and cooling water comprise a major portion of water used by industry in the basin. Mineral quality of boiler feed water is an important factor in the rate of scale formation on heating surfaces, degree of corrosion in the system, and quality of produced steam. In cooling water systems, resistance to slime formation and corrosion is affected by mineral quality.

4. User Alternatives. The physical impacts of salinity upon consumptive uses of water were translated into economic values by evaluating how each user might alleviate the effects of salinity increases.

a. Municipalities could:

(1) Do nothing and the residents would consume more soap and detergents or purchase home softening units or experience accelerated frequency of replacement of water facilities.

(2) Build central water softening plants.

(3) Develop new, less mineralized water supplies.

b. Industrial users could combine more extensive treatment of their water supply with the purchase of additional makeup

water based upon the economics of prevailing conditions. The required mineral quality levels are maintained in boiler and cooling systems by periodically adding an amount of relatively good quality water (makeup water) and discharging from the system an equal volume of the poorer quality water (blowdown).

c. The alternatives available to irrigation water users are influenced by the availability of additional water. The primary means of combating detrimental salinity are to switch to more salt tolerant varieties of present crops, switch to substitute crops less affected by salinity, or to apply more irrigation water to keep the excess salts moving out of the root zone.

(1) If the irrigator does nothing, he will suffer economic loss from decreased crop yields.

(2) If additional water is available, root zone salinity may be reduced by increasing leaching water applications. The irrigator would incur increased costs for purchase of water, for additional labor for water application, and for increased application of fertilizer to replace the fertilizer leached out.

(3) If no additional water is available, the irrigator can increase the leaching of salts from the soil by

applying the same amount of water to lesser acreage.

This, of course, results in an economic loss since fewer acres of crops can be grown.

(4) By changing the management regime and applying alternative production practices, some salinity effects can be mitigated but only by incurring additional costs.

These alternatives include drain installation, ditch lining, land leveling, deep plowing, planting bed modification, sprinkler and drip irrigation, and increased irrigation frequency.

(5) The last alternative is to plant salt tolerant crops.

An economic loss would usually occur since many salt tolerant crops ordinarily produce a lower economic return.

5. Economic Evaluation. The cost of applying each of the alternative remedial actions was determined, and the least costly alternative selected for subsequent analyses. For industrial use, an estimate of required makeup water associated with salinity increases was selected to calculate the penalty cost. Municipal damages were estimated by calculating the required additional soap and detergents needed, physical damages to facilities, and the cost of central softening.

Economic studies were intended to provide a basis for assessing the economic impact of a change in salinity levels. Water quality, water use patterns, and economic conditions were projected and appropriate discounts made to arrive at representative values. Direct penalty costs were then aggregated for the entire impact area.

Because of the interdependence of numerous economic activities, there exist indirect effects on the regional economy stemming from the direct economic impact of salinity upon agricultural water users. These effects, termed indirect penalty costs, can be determined if the interdependency of economic activities is known. A simple ratio of direct to indirect impacts was used based on the EPA study wherein an "input-output model" was developed to follow changes affecting any agricultural industry through a chain of transactions in order to identify secondary or indirect effects on the economy stemming from the direct economic costs of salinity.

B. Agricultural Impacts

A number of salinity adaptation practices are presently known which can help to alleviate crop yield decreases caused by increasing water and soil salinity. As the level of sophistication of

farm management practices increases, crop production costs generally increase accordingly. These increased costs attributed to salinity adaptation can be considered as economic detriments.

The EPA chose the yield decrement method to best represent the agriculture damages associated with all the lower basin areas and assumed no change in farm management practices, the amount of water applied or the number of acres farmed. However, indications are strong that farmers will most likely adopt feasible salinity adaptation practices rather than suffer yield losses or reduce acreage. Management practices which are or can be implemented by farmers to mitigate salinity impacts are briefly reviewed below:

1. As salinity and water costs increase, ditch lining is almost mandatory as a method of reducing seepage losses and alleviating soil salinization. Land leveling is necessary for uniform distribution of water and the prevention of salt buildup in high spots in a field.
2. Moldboard and slip plowing to depths of 4 to 6 feet are practical and result in improved drainage efficiency and more uniform water penetration.

3. Salts generally accumulate in the soil surface during the period of crop maturation when water is not being applied or in hills during conventional furrow irrigation. Leaching to move salts down and reduce soil salinity in the root zone is necessary before planting the next crop.

4. For leaching to be effective, a good drainage system must be provided. Tile drains generally increase the efficiency of water removal. Necessary drainage for maintaining a salt balance could also be considered an economic detriment.

5. Special bedding practices such as double-row beds or sloping beds can achieve better salinity control by affecting the location of the salt buildup during the cropping period in relation to plant placement.

6. A significant advantage of sprinkler irrigation over furrow or flood irrigation is the movement and buildup of salt in the surface layers of the soil. Sprinkler irrigation eliminates salt accumulation in conventional furrow irrigation beds and results in more efficient salt removal and lower root zone salinities than with flood irrigation.

7. Drip irrigation could be used for a number of crops but the costs are substantial. Water with very high concentrations of TDS can be used on many crops with this system, but periodic leaching would be necessary to remove salts accumulated at the lateral edges of the flow pattern.

8. Increased irrigation frequency with flood or furrow systems to maintain optimally low osmotic plus matrix stresses is an alternative to drip or sprinkler irrigation. This could be facilitated with moisture measuring devices such as tensiometers or by an irrigation scheduling service.

9. Replacing citrus or other fruit root stocks which are sensitive to chloride or sodium ions with root stocks which do not accumulate these ions as rapidly is another alternative management possibility.

The assumptions used in evaluating economic effects of salinity on irrigated crops in the Lower Colorado River Basin are given below:

1. The basis for determining the direct salinity effect per mg/l was Sun's 1972 study (Reference 13), which dealt directly with measuring the effects of utilizing water of differing dissolved solids content on optimal irrigation scheduling practices and product mix in the Imperial Valley. In addition to

its importance as an advance in the conceptualization of the problem of measuring damages due to salinity, it also constitutes the only analysis comparable in scope to the EPA's estimates of agriculture damages in the Lower Colorado River Basin.

The Sun approach to predicting crop response to soil salinity and irrigation scheduling involved a programming model incorporating 1,944 processes. The processes reflected each of nine crops on each of three soil types in each of six subregions of the Imperial Valley for each of three farm sizes. For each of these in turn, a process was developed for three irrigation scheduling rules and four levels of intake water quality (mg/l = 480, 960, 1,280, and 1,920). The model was solved to derive net regional income for the four levels of water quality.

Setting the net returns with mg/l at 960 equal to 100 percent (which Sun defined as current 1970 salinity level), expected net returns decrease 12-15 percent when the mg/l is 1,280. Changes in net returns may be explained by the changes in total crop acreage, production of high valued crops, adoption of leaching fraction and moisture depletion percentage.

The change of optimum crop production from mg/l of 960 to 1,280 resulted in a reduction of net annual farm income of \$7,594,427.

The regional model encompassed 469,200 acres resulting in \$16 per acre reduction in net farm income. This was reduced to mg/l per acre by dividing \$16 per acre by 320 mg/l change in salinity concentration. The result is a penalty of \$0.05 per mg/l per acre per year. The above values become the basis for computing a penalty cost for the remaining areas in the Lower Colorado River Basin.

2. The Lower Colorado River Basin was divided into three study areas by EPA which included Southern California, Lower Main Stem, and the Gila area. Within these study areas, irrigation districts or Bureau of Reclamation projects were identified which would be representative and for which information regarding crop value was available. Tables 1 through 9 give the crop production pattern and acreage for each area delineated.

Data for these areas were given as gross crop value. For this to be comparable to the base area (Imperial Valley), this had to be reduced to a net value. Since information to do this was not available, judgment and experience indicated that gross crop value should be reduced by approximately 55 percent. The 55 percent would be representative of annual fixed and variable cost of production.

Table 1

SOUTHERN CALIFORNIA STUDY AREA

Imperial Irrigation District (1972)

<u>Crop</u>	<u>1972 acres</u>	<u>Percent</u>
Field crops ^{1/}	473,008	84
Garden crops ^{2/}	71,785	13
Permanent ^{3/}	15,551	3
	<u>560,344</u>	<u>100</u>

^{1/} Field crops - includes alfalfa, small grains, grasses, sugar beets.

^{2/} Garden crops - vegetables.

^{3/} Orchards - citrus.

Table 2

SOUTHERN CALIFORNIA STUDY AREA

Imperial County (1972)

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Field crops	674,680	89	\$ 166.73	\$112,487,000
Vegetable crops	77,120	10	1,208.17	93,174,000
Fruit and nut crops	2,687	1	547.45	1,471,000
	<u>754,487</u>	<u>100</u>	<u>\$ 274.53</u>	<u>\$207,132,000</u>

Source: Imperial County Agriculture 1972, Office of the Agriculture Commissioner.

Table 3

SOUTHERN CALIFORNIA STUDY AREA

Coachella Valley (1972)

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Field crops	12,338	23	\$ 124.52	\$ 1,536,390
Vegetable crops	13,629	25	1,026.40	13,988,799
Fruits	<u>29,179</u>	<u>52</u>	<u>1,514.26</u>	<u>42,670,350</u>
	54,146	100	\$1,074.79	\$58,195,539

Source: Annual review - Coachella Valley County Water District
(1971-1972).

Table 4

SOUTHERN CALIFORNIA STUDY AREA

San Diego^{1/}

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Vegetables and fruits	66,700	100	\$1,200.00 ^{2/}	\$80,040,000

- 1/ Assumptions: a. By 1980 the MWD deliveries would be a blend of Colorado River and Feather River waters.
b. That the blended irrigation water would be diluted uniformly by an average annual rainfall of 9 inches. (It should be recognized that the economic effects are dampened considerably by these two assumptions.)
- 2/ \$1,200/acre value based on Coachella Valley per-acre value of vegetables and fruits.

Table 5

SOUTHERN CALIFORNIA STUDY AREA

Palo Verde Irrigation District

<u>Crop</u>	<u>1972 acres</u>	<u>Per-acre net value</u>
Field crops	103,800	\$132.00 ^{1/}

^{1/} Net per-acre value was assumed to be the same as Imperial Valley.

Table 6

GILA STUDY AREA

Salt River Project (1971 data)

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Field crops	233,420	96	\$149.75	\$34,955,139
Vegetables	1,846	1	166.54	3,107,428
Seeds	3,005	1	405.60	1,218,839
Fruits	4,904	2	457.24	2,242,328
	<u>243,175</u>	<u>100</u>	<u>\$170.75</u>	<u>\$41,523,734</u>

Source: Crop Report - Bureau of Reclamation.

Table 7

GILA STUDY AREA

Wellton-Mohawk Project (1971 data)

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Field crops	65,300	62	\$ 192.97	\$12,600,953
Vegetables	10,429	10	1,113.40	11,611,606
Seeds	8,736	8	390.27	3,409,410
Fruits	20,092	20	620.75	12,472,122
	<u>104,557</u>	<u>100</u>	<u>\$ 383.46</u>	<u>\$40,094,091</u>

Source: Crop Report - Bureau of Reclamation.

Table 8

LOWER MAIN STEM STUDY AREA

Colorado River Indian Reservation (1971 data)

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Field crops <u>1/</u>	101,360	100	<u>2/</u> \$210	\$21,285,600

1/ Barley, sorghum, grain, cotton.

2/ Per-acre value based on Yuma Project field crops - \$211.94.

Table 9

LOWER MAIN STEM STUDY AREA

Yuma Project (1971 data) 1/

<u>Crop</u>	<u>Acres</u>	<u>Percent</u>	<u>Per-acre value</u>	<u>Total gross value</u>
Field crops	48,107	70	\$ 211.94	\$10,196,109
Fruits	2,745	4	322.58	885,331
Seeds	4,584	7	415.92	1,906,578
Vegetables	<u>13,135</u>	<u>19</u>	<u>1,225.15</u>	<u>16,092,391</u>
	68,571	100	\$ 424.09	\$29,080,409

1/ Crop Report - Bureau of Reclamation.

The net return per acre for the Imperial Valley as determined by the Sun regional model was \$132. The net return per acre for each of the study areas was compared to the \$132, and per acre penalty costs were determined in relation to this base value. Tables 10, 11, and 12 show the conversion to direct salinity detriments per acre for each area.

3. Present modified acres which were the basis for predicting the total salinity effect in mg/l for a given area were based on an average acreage projected by EPA for the time periods of 1960, 1980, and 2010.

The summary of the calculations for each area is given in Table 13. The total direct salinity impacts are \$66,900 per mg/l on an annual basis for 1,076,800 acres or an average of \$0.0621 per acre per mg/l per year. The indirect effects are calculated as 62 percent of the direct effects. This factor is taken from the EPA study which calculated the indirect impacts by use of input/output analysis. The total impact of salinity upon the agricultural users of the Lower Basin is given as \$108,400 per mg/l per year in 1972 dollars.

Table 10

SOUTHERN CALIFORNIA STUDY AREA

Crops and area	Acres	Percent	Per-acre gross value	Per-acre <u>1/</u> net value	Adjustment from <u>2/</u> \$16/acre effect Imperial area	Direct per-acre salinity effect cost
<u>Imperial County</u>						
Regional model	469,200	100		\$132	$\$132/\$132 = 1.0$	\$16
<u>Coachella Valley</u>						
Field crops	12,338	23	<u>3/</u> \$ 124.52	56	$56/\$132 = 0.42$	7
Vegetable crops	13,629	25	<u>3/</u> 1,026.40	462	$462/\$132 = 3.50$	56
Fruits	<u>28,179</u>	<u>52</u>	<u>3/</u> <u>1,514.26</u>	<u>681</u>	<u>$681/\\$132 = 5.16$</u>	<u>83</u>
Total or weighted average	54,146	100	\$1,074.79	\$484	$\$484/\$132 = 3.67$	\$59
Applicable acres =	40,800					
<u>MWD (San Diego)</u>						
Vegetables and fruits	70,900	100	<u>4/</u> \$1,200.00	\$540	$\$540/\$132 = 4.09$	65
<u>Palo Verde</u>						
Field crops	103,800	100		<u>5/</u> \$132	$\$132/\$132 = 1.0$	16

1/ Net value computed on basis fixed and variable costs of production will approximate 55 percent of gross value.

2/ Base value \$16/acre salinity effect Imperial Valley, Sun, Po-Chuan (1972). "An Economic Analyses of the Effects of Quantity and Quality of Irrigation Water on Agricultural Production in Imperial Valley, California." Ph.D. dissertation, University of California, Davis.

3/ Annual review Coachella Valley County Water District - 1971-1972.

4/ Gross value was an interpolation from Coachella Valley vegetables and fruits.

5/ Net per-acre value assumed to be same as Imperial Valley with similar cropping pattern.

Table 11

GILA STUDY AREA

Crops and area	Acres	Percent	Per-acre <u>1/</u> gross value	Per-acre <u>2/</u> net value	Adjustment from <u>3/</u> \$16/acre effect Imperial area	Direct per-acre salinity effect cost
<u>Salt River Project</u>						
Field crops	233,420	96	\$ 149.75	\$ 67	\$ 67/132 = 0.51	\$ 8
Vegetables	1,846	1	166.54	75	75/132 = 0.57	9
Seeds	3,005	1	405.60	183	183/132 = 1.38	22
Fruits	4,904	2	457.24	206	206/132 = 1.56	25
Total or weighted average	243,420	100	\$ 170.75	\$ 77	\$ 77/132 = 0.58	9
<u>Gila Project</u>						
Field crops	65,300	62	\$ 192.97	\$ 87	\$ 87/132 = 0.66	\$11
Vegetables	10,429	10	1,113.40	501	501/132 = 3.80	61
Seeds	8,736	8	390.27	176	176/132 = 1.33	21
Fruits	20,092	20	620.75	279	279/132 = 2.12	34
Total or weighted average	104,557	100	\$ 383.46	\$173	\$173/132 = 1.31	\$21

1/ Bureau of Reclamation annual crop report.

2/ Net value computed on basis fixed and variable costs of production will approximate 55 percent of gross value.

3/ Base value \$16/acre salinity effect Imperial Valley, Sun, Po-Chuan (1972). "An Economic Analyses of the Effects of Quantity and Quality of Irrigation Water on Agricultural Production in Imperial Valley, California." Ph.D. dissertation, University of California, Davis.

Table 12

LOWER MAIN STEM STUDY AREA

Crops and area	Acres	Percent	Per-acre gross value	Per-acre <u>1/</u> net value	Adjustment from <u>2/</u> \$16/acre effect Imperial area	Direct per-acre salinity effect cost
<u>Colorado River Indian Reservation</u>						
Field crops	72,000	100	<u>3/</u> \$ 210.00	\$ 95	\$ 95/132 = 0.72	\$11
<u>Yuma Project</u>						
Field crops	48,107	70	<u>4/</u> 211.94	95	95/132 = 0.72	12
Fruits	2,745	4	<u>4/</u> 322.58	145	145/132 = 1.10	18
Seeds	4,584	7	<u>4/</u> 415.92	187	187/132 = 1.42	23
Vegetables	<u>13,135</u>	<u>19</u>	<u>4/</u> <u>1,225.15</u>	<u>551</u>	<u>551/132 = 4.18</u>	<u>67</u>
Total or weighted average	68,571	100	\$ 424.09	\$191	\$191/132 = 1.45	\$23

1/ Net value computed on basis fixed and variable costs of production will approximate 55 percent of gross value.

2/ Base value \$16/acre salinity effect Imperial Valley, Sun, Po-Chuan (1972). "An Economic Analyses of the Effects of Quantity and Quality of Irrigation Water on Agricultural Production in Imperial Valley, California." Ph.D. dissertation, University of California, Davis.

3/ Gross value based on gross crop value of Yuma Project with similar cropping pattern.

4/ Bureau of Reclamation annual crop report.

Table 13

SUMMARY OF DIRECT AND INDIRECT SALINITY IMPACTS
ON AGRICULTURAL USERS BY AREA

Area	Salinity effects per acre	Cost 1/ mg/l per acre	Present modified acres	Total salinity effect cost per mg/l/year
<u>Southern California</u>				
Imperial County	\$16	\$0.050	526,000	\$ 26,300
Coachella Valley 2/	59	0.184	40,800	7,500
MWD (San Diego) 3/	65	0.203	32,500	6,600
Palo Verde	16	0.050	103,800	5,200
<u>Lower Main Stem</u>				
Colorado River Indian Reservation	11	0.034	72,000	2,500
Remainder Yuma County	23	0.072	146,000	10,500
<u>Gila Area</u>				
Salt River Project (CAP area) 4/	9	0.028	50,700	1,400
Gila Project	21	0.066	105,000	6,900
TOTAL			1,076,800	\$ 66,900
Indirect effects - $0.62 \times 66,900$				41,500
TOTAL				\$108,400

1/ Cost per mg/l per acre was based on Sun's 1972 study which predicted a crop response to change in salinity concentration of 320 mg/l. $\frac{\$16}{320 \text{ mg/l}} = \$0.05 \text{ mg/l/acre.}$

2/ Twenty percent of the irrigation water comes from wells. The 40,800 acres represent 80 percent of present modified acres.

3/ Represents only that portion of agricultural lands which will not receive a blended water supply.

4/ Based on full service ground-water exchange acre equivalent of the CAP area that can be served with Colorado River water. (5.72 acre-feet per acre at canal side).

C. Municipal Impacts

A high dissolved solids content of water distributed by a municipality will adversely affect its individual users. Such adverse effects relate to the aesthetic quality of the water and to the operating and maintenance costs associated with its beneficial use. During the past 10 to 15 years, a number of investigators have studied the relationship between composition of water supplied to a municipality and costs associated with the use of water-connected facilities. The data which have been gathered are not altogether consistent. Investigators have not studied the same ranges of dissolved solids and much more research is needed. However, some monetary benefits of water improvement have been identified and from these it is possible to prepare estimates of the tangible advantages of reducing the dissolved solids and hardness level of a municipal water supply.

It has always been recognized that the consumption of soap and detergents would be greater in areas of hard water. Other costs resulting from water hardness include treatment for softening, wear on clothing, reduced life of cooking utensils, and scaling of water heaters and piping. In almost all natural waters, hardness is caused by calcium and magnesium ions.

Items affected and repairs necessitated by the corrosiveness of water include water heaters, piping and fixtures, water damage from broken appliances, and swimming pool heaters.

Some people have special water quality requirements for health reasons. Physicians prescribe bottled water for some to restrict their sodium intake.

Persons who do not like the taste, odor, or appearance of a water supply may turn to other sources. Taste can be caused by inorganic or organic material. An individual's perception of the taste of water is subjective and is influenced by the quality of the supply which he is accustomed to drinking. Nevertheless, the presence of certain dissolved salts does affect taste and is readily detected by most people. If the concentration of dissolved salts is too large, the water is considered unpalatable and bottled water may be substituted.

Household damages due to salinity have been estimated by a number of researchers. An array of the calculated costs is shown in Table 14. The Orange County and the Black and Veatch studies are the most complete of those available. From these two studies and other information available from various salinity reports, an estimated value for each of the household items was derived. Not all

Table 14

SALINITY IMPACTS

Annual Cost (Dollars) per Household per mg/l of TDS

Cost Item/Report	Orange County	Santa Ana watershed	Black and Veatch	OSW Report 779	Metcalf and Eddy	De Boer and Larson	Orange County connected by MWD	Values for lower main stem	Values for CAP area	Values for MWD Area	Low estimate	High estimate
Purchase of cleaning agents	0.0880		0.0046	0.0600	0.1143	0.0293	-	0.0050	0.0050	0.0050	0.0046	0.0293
Home water softener	.0693			.0500			0.0122	-	-	-	-	-
Bottled water	.0286	0.0100	.0600	.0100	.0091		.0171	.0171	.0171	.0171	.0091	.0286
Water heater	.0423		.0137				.0047	.0137	.0137	.0137	.0047	.0423
Water piping and wastewater	.0693		.0148				.0108	.0108	.0108	.0108	.0108	.0310
Faucets and fixtures	.0100		.0080				.0086	.0086	.0086	.0086	.0086	.0150
Toilet mechanism	.0020		.0050									
Garbage disposal	.0100											
Clothes and dishwasher	.0200		.0080				.0117	.0117	.0117	.0117	.0080	.0200
Water damage	.0030						.0007	-	-	-	-	-
Swimming pool cleaning	.0020						.0018	-	-	-	-	-
Washable fabrics			.0126					-	-	-	-	-
Lawn watering			.0100					-	-	-	-	-
Plumbing and appliances (composite)		.0800						above	above	above	-	-
Water utility system			.0068					-	-	-	-	-
Sewage facilities			.0011					-	-	-	-	-
Meter damage								-	-	-	-	-
Central softening							.0056	.0085	.0085	.0056	.0056	.0085
TOTAL	.3445	.0900	.1446	.1200	.1234	.0293	.0732	.0754	.0754	.0725	.0514	.1747

of the household items that might be affected by salinity in other reports were used because of lack of enough evidence that a real detrimental effect occurs. The individual items used were those which were judged to be important and relevant to the average home in the Lower Colorado River area.

The Lower Colorado River Basin was analyzed as three separate areas. The areas are (1) the Metropolitan Water District of California, (2) the Central Arizona Project service area, and (3) the Lower Main Stem municipal service area which includes cities along the Colorado; in the Imperial Valley; and Las Vegas, Nevada, including surrounding cities.

The Metropolitan Water District water from the Colorado River will be blended with State Water Plan water with the salinity levels eventually falling to about 350 mg/l according to current estimates. The equivalent full service capability of the portion of the 550,000-acre-foot Colorado River diversion after 1987 used by households and the larger diversions up to that time amount to about 1,181,000 homes on a present worth basis. It is assumed the 1973-1987 diversion will be about 1,052,000 acre-feet for municipal use. Diversion will be cut back to 550,000 acre-feet in 1987 with 400,000 acre-feet used for municipal purposes. Calculations are based on 0.67 acre-foot per household per year. In order to mitigate the effects of the salt contained in the waters from the Colorado River, it is assumed that central softening will be available to all users at a cost of \$0.0056 per mg/l per year with additional homeowner costs of

\$0.0669 per mg/l per year for a total of \$0.0725 per household. The annual detriments for this service area would then total \$85,600. Using a range of values given in Table 14 to reveal the uncertainty associated with this estimate, this value could vary from \$60,700 to \$206,300.

While firm numbers are not yet fully established, a reasonable estimate suitable for the purpose at hand for the Central Arizona Project is that some 237,400 households on a present worth basis will be serviced with Colorado River water beginning in 1987. Household use is estimated at 0.76 acre-foot per household per year. The detriments per household per mg/l per year amount to \$0.0754 with the water centrally softened for a cost of \$0.0085 per mg/l per household per year. The total annual detriment would be \$17,900. Using a range of values given in Table 14 to reveal the uncertainty associated with this estimate, this detriment could vary from \$12,200 to \$41,500.

Associated with the Lower Main Stem service area of the river are 212,700 households on a present worth basis of projected growth. The projections of growth of the towns and cities along the lower main stem of the Colorado River were discounted to the present and put on an annual basis. In addition to service to the Las Vegas Valley, full service was assumed to be available to Boulder City, Nevada; Parker, Yuma, Kingman, Havasu City, and Mohave Valley, Arizona;

Needles, Blythe, El Centro, Brawley, and Calexico, California, and other smaller communities. The detriments per household per mg/l per year amount to \$0.0754 which when multiplied by the number of households give a total damage for the area on an annual basis of \$16,000. This is a most likely value. Using a range of values given in Table 14, this value could vary from \$10,900 to \$37,200.

The summary of economic impacts upon municipal users is shown in Table 15. The most likely expected total for the three areas is \$119,500 per mg/l per year with a reasonable range of from \$83,800 to \$285,000.

D. Industrial Impacts

The effect of water quality on industrial uses is difficult to generalize because of the varied uses to which industry puts water.

Industrial water use may be classified by purpose as cooling, boiler feed, process, or general purpose. When raw water does not meet quality criteria for the various purposes, treatment methods include water softening, evaporation, demineralization, chromatic addition, and chlorination in cooling systems for control of corrosion and slime.

The quality of boiler feed water is a significant factor in the (1) rate of scale formation on heating surfaces, (2) degree of corrosion to the system, and (3) quality of produced steam.

Table 15

SUMMARY OF SALINITY IMPACTS ON MUNICIPAL USERS
(Dollars per mg/l per year)

Metropolitan Water District	\$85,600
Central Arizona Service Area	17,900
Lower Main Stem Service Area	<u>16,000</u>
TOTAL	\$119,500
Range -	\$83,800 to \$285,000

Cooling water is used for a variety of purposes, including the cooling of condensers, internal combustion engines, and compressors. Among the constituents of natural water that may prove detrimental to its use for cooling purposes are hardness and suspended solids.

Process water is used in preparation of the products of industry. This water is either incorporated directly into the finished product or used in transporting, mixing, washing, dissolving, concentrating, or cooking operations.

General purpose water is used by industry for plant personnel needs, general cleaning, lawn watering, and fire protection.

Using data from the EPA study, the total industrial detriments per mg/l per year are estimated at \$1,500 for the entire Lower Basin area.

E. Total Economic Impacts Due to Changes in Salinity Levels

The calculations of the total economic impact of changing salinity levels on the Colorado River are simply a summation of the impacts upon individual users. This summary is given in Table 16.

The agricultural impacts are divided into direct and indirect with the total being \$108,400 per mg/l per year.

Table 16

SUMMARY OF SALINITY IMPACTS ON ALL USERS
(Dollars per mg/l per year)

Agricultural impacts		\$108,400
Direct	\$ 66,900	
Indirect	41,500	
Municipal impacts		119,500
Low estimate	83,800	
High estimate	285,000	
Industrial impacts		<u>1,500</u>
Total impacts		\$229,400
Low estimate	193,700	
High estimate	394,900	
Direct impacts		187,900
Low estimate	152,200	
High estimate	353,400	

No secondary impacts are assumed for municipal damages but a range is given bracketing the most likely value due to the high variability of the estimates of municipal damages. The total impacts expected to be faced by municipalities are \$119,500 per mg/l per year.

Industrial impacts are minimal amounting to only \$1,500 per mg/l per year for the entire lower basin.

The total impacts are given as \$230,000 per mg/l per year with \$41,500 of indirect impacts associated with agriculture. The expected direct impacts are \$188,000 per mg/l per year with a reasonable range of from \$152,000 to \$353,000 per mg/l per year.

These figures should be thought of as the best possible estimates at this point in time. Research is continuing to further refine and delineate the economic impact of changing salinity levels on the Colorado River.

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